compensation (resulting in a sustained improvement in performance) for the effect of variation of the magnetic field within the working volume with time whilst the current flow in the main coil assembly (1; 1') and the B0 shim coil assembly (2; 2') remains superconducting.

Attached is an Appendix showing the above amendments to claim 1 in annotated form.

REMARKS

The application has been amended as needed so as to place it in condition for disposal at the time of the next official action.

In the course of this revision, subject headings have been inserted at the appropriate locations throughout the specification in a manner consistent with the preferred guidelines set forth at Section 601 of the Manual of Patent Examining Procedure (MPEP).

The objections under 35 U.S.C. 112 have been disposed of by appropriate amendment of lines 6 and 17 of Claim 1. It has been assumed that the Examiner has no difficulty with the meaning of the art term "shim" which is also used by Yamaguchi et al. and is in any case followed by the wording "for providing fine adjustment of the central magnetic field" in the claim wording. Accordingly a definition of "B0" has merely been added to the claim wording.

With regards to line 17 of the claim the wording "(resulting in a sustained improvement in performance)" has been added after the term "significant compensation" in order to make it clear that the wording "significant compensation" is used to denote a level of compensation which is used to lead to a significant improvement in the system performance, as opposed to a substantially chance variation of the magnetic field that might cause a purely incidental compensation effect at a low level. As is apparent from the definition of the term provided on page 5/1 of the specification, the controlled compensation provided in the apparatus of the invention may be such as to enable an experiment to be carried that would not be possible in the absence of such compensation.

One example that comes to mind is where there is an external disturbance (e.g. as a result of disturbance due to a nearby railroad) during an experiment without such compensation, and the effect on the data of such disturbance is at a comparable level to the effect being investigated. This can be a very real problem at some sites and certain sensitive experiments cannot be successfully undertaken unless something is done to compensate for the disturbance. It would also include situations where an experiment or application *could* be performed without compensation, but where the experiment could give significantly better quality data (e.g. better resolution spectra) or where the experiment could be performed more efficiently (e.g. with a more dilute sample or over a shorter time period) with the application of the required "significant compensation". The significant benefits of this in academic applications in terms of publishable results or in industrial applications in terms of throughput are obvious.

In either category, the significant compensation could require an order of magnitude improvement in the temporal stability of the central magnetic field, but it could equally well require an improvement of only a few tens of percent to prove significant. For example, some experiments would be just achievable if the central field were varying (e.g. due to magnet drift) at a rate of 0.015 ppm/hour, but not if the rate were 0.02 ppm/hour.

Claims 1 - 14 were rejected under 35 U.S.C. 103(a) as being unpatentable over Yamaguchi et al. in view of Toyoda et al. Claim 1 has been amended so as to emphasise the patentability of the invention claimed over the cited references, and it is submitted that amended Claim 1 is now clearly allowable for the reasons that are set out below.

A new claim, Claim 15, has been added, this claim corresponding to Claim 7 rewritten in independent form including all of the limitations of the base claim and any intervening claims, and accordingly it is submitted that the new Claim 15 is allowable.

A further new claim, Claim 16, has been added corresponding to Claim 10 rewritten in independent form including all of the limitations of the base claim and any intervening claims, and it is submitted that Claim 16 is also allowable.

Yamaguchi et al discloses non-superconducting NMR imaging apparatus incorporating shim coils to compensate for the static field distribution to obtain the

desired uniformity of the field within the imaging area to provide a high quality tomographic image. Before commenting on this reference further it should be stressed that this reference does not relate to superconducting electromagnet apparatus, and as such is largely irrelevant to the invention with which the claims of the present application is concerned. This is because the design of non-superconducting electromagnet apparatus and the design of superconducting electromagnet apparatus are quite different arts, and there is no reason why a person skilled in the art of superconducting electromagnet apparatus should look to the literature of non-superconducting electromagnet apparatus to solve a particular problem in the control of superconducting electromagnet apparatus.

Superconducting electromagnet apparatus is much more complicated in design than non-superconducting electromagnet apparatus, and is capable of producing magnetic fields which are an order of magnitude greater than the fields achieved with non-superconducting electromagnet apparatus. Not only does superconducting electromagnet apparatus require the means for supplying cooling fluid to enable superconducting current flow in the coils, but also it requires a suitable control arrangement for sustaining the superconducting current flow once this has been initiated. The problems encountered in control of the current flows, and hence in control of the central magnetic field, in superconducting electromagnet apparatus are quite different to the problems encountered in the control of the magnetic field of non-superconducting electromagnet apparatus. More particularly the particular problem of "drift" of the superconducting current, as a result of the fact that the residual resistance of the superconducting main coils increases significantly as the operating current becomes

comparable with the critical current of the coils, is not encountered in use of non-superconducting coils.

Even leaving aside this important distinction between the field with which Yamaguchi et al. is concerned and the field with which the present invention is concerned, and the different considerations to be taken account of in design of apparatus in such fields, Yamaguchi et al. does not provide any new teaching over and above what is discussed in the introduction to the specification referring to the use of compensating coils in the superconducting electromagnet apparatus of EP 0468425A. Yamaguchi et al. uses a shim control circuit 6 which has a signal supplied from sequence controller 22 (column 3, lines 27-56). The control circuit 6 may comprise a computer having a memory storing values of currents to be applied to the shim coils to obtain the required field uniformity. Although it is specified that data for variation in the static field may be included in the memory, it is not seen how such an arrangement could compensate for unpredictable variations in the ambient magnetic fields with respect to time.

Not only does Yamaguchi et al. not disclose means "for persisting the superconducting current flow in the main coil assembly when a desired constant current level has been reached" as required by the wording of claim 1, but also it does not incorporate the essential features of claim 1 that (i) the shim coil assembly comprises "superconducting shim coil means connected within a closed loop", and (ii) auxiliary current supply means are provided "for supplying current to the closed loop, and for persisting the superconducting current flow in the closed loop when a desired constant

current level has been reached". The control circuit 6 of Yamaguchi et al. does not provide either of these functions, and there is nothing in Yamaguchi et al. to suggest how such control of the superconducting currents in the main coil assembly (1; 1') and the B0 shim coil assembly (2; 2') of the invention might be exercised.

Of course there is also nothing in Yamaguchi et al. to suggest compensation for the effect of variation of the magnetic field within the working volume with time "whilst maintaining the superconducting current flows in the main coil assembly (1; 1') and the B0 shim coil assembly (2; 2')" as required by the wording of claim 1.

Although the Examiner has accepted that Yamaguchi et al. does not disclose "the coils being superconductive", he has contended that "it would have been obvious to one having ordinary skill in the art at the time that the invention was made to use a superconducting magnet for the magnet coil system of Yamaguchi et al, as suggested by Toyoda et al. It is not clear whether the Examiner is here contending that it would have been obvious at the date of the invention for the main coils of Yamaguchi et al. to be replaced by superconducting coils (even though the control system of Yamaguchi et al. was designed for non-superconducting coils), and/or that it would have been obvious at the date of the invention for the shim coils of Yamaguchi et al. to be replaced by superconducting coils (even though there is no disclosure in Toyoda et al. of shim coils for providing fine adjustment of the magnetic field).

In this regard it should be pointed out that Toyoda et al. was also referred to in the International Preliminary Examination Report dated June 12, 2001, and that the Internatioanl Examiner appears to have made a serious error in his interpretation of what is disclosed in this reference (which was apparently responsible for the Examiner incorrectly concluding that the subject matter of claims 1 and 2 is disclosed in this reference). The Examiner identified the component 5 in Figure 1 of Toyoda et al. as being "a superconducting shim coil assembly". However this is a misreading of Figure 1 as 5 denotes a heater supplied with current from a heater power source 6 (column1, lines 40-51). Thus there is no disclosure in Toyoda et al. of a superconducting shim coil assembly for providing fine adjustment of the central magnetic field (let alone any disclosure of such a shim coil assembly being adapted to effect temporal variation of the magnetic field. Instead any time variation of the magnetic field in Toyoda et al. is effected solely by control of the main superconducting coil assembly 1 utilising the disclosed control circuitry.

It follows that there is no disclosure of a superconducting shim coil assembly in *either* Yamaguchi et al. *or* Toyoda et al., and accordingly it cannot be considered to have been obvious to one having ordinary skill in the art at the time that the invention was made to use a superconducting magnet for the shim coil system of Yamaguchi et al. It is made quite clear in Yamaguchi et al that the shim coil assembly disclosed therein is constituted by normally conductive coils, and there is nothing in this reference, or in Toyoda et al., to suggest making use of a superconducting shim coil assembly to effect both the B0 shim function and fine tuning of the central magnetic field with time. There

is no reason why the skilled person should consider making any changes to the shim coil assembly of Yamaguchi et al.

It should also be pointed out that the shim coil assembly of Yamaguchi et al. could not be used to compensate for a magnetic field variation with time due to the residual resistances of the superconducting coil assemblies, since, in the field of control of large magnetic fields such as are encountered in use of superconducting electromagnet apparatus, the interactions between magnet assemblies can produce effects which swamp the magnetic correction effects which they are intended to compensate and which can themselves result in magnetic inhomogeneities. It will be appreciated from the description with reference to the drawings of the present application that the design of the superconducting coil assemblies must be carried out carefully to ensure that the necessary temporal compensation is provided by the B0 shim coil assembly as required.

For example, in a practical embodiment, the superconducting main coil assembly may be set to produce a central magnetic field of approximately 9.4 T corresponding to a main operating current of 89 A. A typical minimum requirement for a NMR magnet would be to set the central magnetic field to an accuracy of better than ± 3 mT. The shim coil assembly is used to compensate for any small departures of the central magnetic field from the ideal value. For example the shim coil assembly might be used to reset the central magnetic field when it departs from its required value by applying an auxiliary current of approximately 2A to the shim coil assembly. Such fine adjustment

can be effected much more straightforwardly using such an shim coil assembly rather than by adjusting the main current supply to the main coil assembly by 250 mA from 89 A.

In addition to the sensitivity criterion, there are other reasons as to why it is advantageous to be able to effect fine adjustment in this manner without being required to open the main magnet switch to directly run current through the whole of the main magnet current circuit. Firstly the chances of the main coil assembly quenching during the procedure are significantly reduced. Furthermore the control circuitry required to operate the shim coil assembly is less complicated and costly than that which would be required to operate the main coil assembly directly, and the setting time of the circuit is normally less because of the lesser inductance of the shim coil assembly.

Accordingly it is submitted that amended Claim 1 is clearly patentable over Yamaguchi et al. in view of Toyoda et al. Furthermore, because each of Claims 2 to 14 is appended directly or indirectly to amended Claim 1, it is submitted that each of these claims is similarly patentable over these two references. Furthermore Jayakumar made of record but not relied upon does not deprive any of these claims of patentable subject matter, whether Jayakumar is considered on its own or in combination with the other references. This is because Jayakumar is concerned with superconducting electromagnet apparatus incorporating compensating coils in which currents are produced by induction under the effect of the currents supplied to the main coils. This is quite different from the shim coil arrangements of both the invention of claim 1, and Yamaguchi et al., in which the compensating currents are supplied from auxiliary current supply means separate from

the current supply means for the main coils. Clearly the provision of separate auxiliary current supply means provides a considerably greater degree of control of the magnetic field.

In view of the present amendment and the foregoing remarks, therefore, it is believed that this application has been placed in condition for allowance. Reconsideration and allowance are accordingly respectfully requested.

Should the Examiner feel that a telephone interview would be helpful to facilitate favorable prosecution of the above-identified application, the Examiner is invited to contact the undersigned at the telephone number provided below.

Should a petition for an extension of time be necessary for the timely reply to the outstanding Office Action (or if such a petition has been made and an additional extension is necessary), petition is hereby made and the Commissioner is authorized to charge any fees (including additional claim fees) to Deposit Account No. 18-0988.

Respectfully submitted,

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APPENDIX

1. (Amended) A superconducting [Superconducting] electromagnet apparatus comprising a main coil assembly (1; 1') for producing a central magnetic field in a working volume, main current supply means (5) connected to the main coil assembly for energising and de-energising the main coil assembly, and for persisting the superconducting current flow in the main coil assembly when a desired constant current level has been reached, in order to generate a central magnetic field of high homogeneity in the working volume, a B0 shim coil assembly (2; 2') for providing fine adjustment of the central magnetic field (B0 being the magnetic field along a central axis), the B0 shim coil assembly comprising superconducting shim coil means connected within a closed loop and arranged to magnetically couple with the main coil assembly (1; 1'), auxiliary current supply means (6) connected to the B0 shim coil assembly for supplying current to the closed loop, and for persisting the superconducting current flow in the closed loop when a desired constant current level has been reached, in order to provide fine adjustment of the central magnetic field within the working volume without significantly degrading the homogeneity of the central magnetic field, and control means (31, 38) for controlling the main and auxiliary current supply means (5, 6), wherein the main coil assembly (1; 1'), the B0 shim coil assembly (2; 2') and the control means (31, 38) are adapted to provide significant compensation (resulting in a sustained improvement in performance) for the effect of variation of the magnetic field within the working volume with time whilst [maintaining] the [superconducting] current flow [flows] in the main coil assembly (1; 1') and the B0 shim coil assembly (2; 2') remains superconducting.